Arabic Roots of the Scientific Revolution

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by: Rim Turkmani **It is well known nowadays that modern Scientific Revolution benefited indirectly from the theories, results and inventions transmitted from the Arabic/Islamic scientific tradition during the Renaissance. The new element introduced by Dr Rim Turkmani who worked for many years on the original archives is that knowledge transfer didn't stop at the Renaissance. In the following original and well-documented article, Dr Turkmani shows that fellows of the Royal Society and scholars at Oxford and Cambridge were openly borrowing ideas and observations from the Middle East throughout the 17th century. Dr Turkmani transferred highlights from these documents and rare books into the Arabick Roots exhibition supported by FSTC and The Qatar Foundation and that was opened at the Royal Society on the 9th of June (see opening coverage here).**

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Table of contents

1. The old ‘new philosophy'
2. Found in translation
3. The book hunters
4. Heavenly problems
5. Reaching out
6. Search and research
7. Arabick material in the collections of the Royal Society
8. Arabick acknowledgment
9. Notes

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1. The old ‘new philosophy'

Plenty of historians of science have studied the impact of Arabic and Islamic science and philosophy on the European Renaissance [1], when Europe was waking up from the Dark Ages and the light of knowledge shone steadily from the East.

Fewer have studied the knowledge transfer that started in the second half of the 16th century and peaked in the 17th. Europe was just giving birth to the scientific revolution, with Francis Bacon (1561–1626) as midwife, and new societies like the Royal Society [2] promulgating the New Philosophy.

Figure 1: Ibn al-Haytham (here Alhasen) sharing with Galileo the honour of holding up the title page of Hevelius' *Selenographia*, pub¬lished in 1647. Note the image of the brain on the plinth below Ibn al-Haytham. *Image courtesy of the library of the Royal Society*.

The late historian of science Marie Boas Hall spent decades editing the correspondence of Henry Oldenburg, secretary of the Royal Society from 1663 to 1677. Struck by his frequent references to Muslim scholars and the need to translate their work, she wrote [3], "At first thought, it seems unlikely that the Fellows of the Royal Society founded by the ‘new philosophy' in England in 1660 ‘for the promotion of natural knowledge', self-confessedly forward looking modernists, should have concerned themselves with Islamic learning. That they did so throws further light upon the complexities of the scientific revolution."

This interest of the ‘New Philosophers' in learning that was eight centuries old might seem surprising. But it becomes less so if we consider the ground they shared with their classical Muslim counterparts, some of whom are acknowledged as pioneers of the scientific method.

Ibn al-Haytham (or Alhazen, 965–c.1040), for example, followed a rigorous research procedure. He started by stating the problem, explicitly supported by observations. He critically reviewed previous work, conducted verifiable experiments to test hypotheses, interpreted the data and formulated conclusions, often mathematically. Only then did he publish his findings. Most modern scientists would follow a similar path. No wonder the pioneers of the scientific revolution could look backwards without betraying their Baconian principles, which demanded complete independence from previous traditions.

Johannes Hevelius, the first foreign Fellow of the Royal Society, expressed the indebtedness of his generation of scientists to Ibn al-Haytham by putting him on the title page of his Selenographia (Fig. 1). There he portrayed al-Haytham as one of the twin pillars of the scientific method, symbolising rational thinking: he stands on a plinth that bears an image of the brain and the Latin word *ratione* (reason).

And although it may come as a surprise that Robert Boyle, the founder of modern chemistry, often turned to the ancient practices of Muslim chemists like Jabir Ibn Hayyan (Geber), Boyle and Geber both championed the experimental approach to chemistry, despite the nine centuries between them. Geber made this clear when he wrote, "The first essential in chemistry is that you should perform practical work and conduct

experiments, for he who performs not practical work nor makes experiments will never attain to the least degree of mastery. But you, O my son, do experiment so that you may acquire knowledge. Scientists delight not in abundance of material; they rejoice only in the excellence of their experimental methods."

Seventeenth-century scientists knew that much essential Muslim knowledge had not yet reached the West. They recognized that the answers to many questions were to be found in Arabic and Persian sources, including masterpieces of Greek mathematics that survived as Arabic versions enriched with commentaries and solutions to equations. Most of the material that seventeenth-century scientists hoped to find in these manuscripts epitomised the new spirit of the Royal Society and the scientific revolution, with its emphasis on empirical data, experimental methods and observations. It was not the theoretical models of Islamic astronomers that interested Edmond Halley and Edward Bernard; it was their remarkably accurate observations and observational methods. Boyle was not interested in knowing to which of the classical elements a substance like sal-ammoniac belonged. His focus was on its description and properties, where it could be found in nature, ways of extracting it and any health and other benefits it might offer. At a time when Islamic medicine was going out of fashion, an interest in Muslim physicians' use of herbs and drugs, and their method of immunising people against smallpox, remained strong.

2. Found in translation

All this scientific and literary activity needed Arabic, and a renewed interest in the language led to the establishment of chairs of Arabic in Cambridge and Oxford. There were other activities, too, such as establishing new embassies and trade missions in the Ottoman Empire, building alliances with Eastern churches and translating the Qur'an, that all needed Arabic. Perhaps because of these diplomatic and religious concerns, any scientific motivation has often been overlooked by historians. But most orientalists of the time did cite scientific as well as religious reasons for studying Arabic [4] and some, like Halley and Greaves, had no other motive.

There is also plenty of evidence that Arabists were actively communicating with scientists and natural philosophers of the time, propagating and translating important Arabic and Persian manuscripts. Frequently, as with astronomers Edward Bernard (1638–1696) and John Bainbridge (1582–1643), the Arabist and the scientist were one and the same.

Scholars also realised that translation had corrupted much of the knowledge that had been transferred during the Renaissance. Science in Europe had now matured enough to care about the details of what was written; details that were often lost in translation. John Bainbridge (1582–1643), the first Savilian Professor of Astronomy at Oxford [5], explained in a letter to the Archbishop of Armagh, James Ussher (1581–1656) that he undertook the difficulty of learning Arabic *'to see with mine own eyes and not be led hoodwink by others'[6].*

Another Savilian Professor of Astronomy, Edward Bernard (1638–1696), obviously had more confidence in Ibn al-Haytham (or Alhazen) than in the translator of his work. Looking for a solution to the long-standing Alhazen problem [7], he wrote to the Royal Society that *'the prolixity of the book proceeds from the ignorance of the interpreter rather than the inelegance of the Arab.'*

3. The book hunters

Arabic and Persian books and manuscripts were at the heart of the 17th-century fascination with Arabic and Islamic science. Scarce in England, they were abundant in the Muslim world, and an active manuscript hunt was necessary to bring them to European libraries. This movement was supported by figures like William Laud (1573–1645), Chancellor of the University and later Archbishop of Canterbury, and James Ussher

(1581–1656), Archbishop of Armagh.

Laud was so keen on collecting and using these manuscripts that he spent his own money on the project, sponsoring travellers to collect them from cities like Constantinople and Aleppo, and most importantly establishing the first Chair of Arabic in England in 1636. Pococke became the first Laudian professor of Arabic and in 1640 Laud endowed the Chair from his own assets. Laud also managed to rally King Charles I to the cause and through him made use of the facilities of the Levant Company to bring books back home. In a letter of 1634 to the English Levant Company, drafted by Laud's secretary, Charles I wrote:

'There is a great deal of Learning and that very fit and necessary to be known, that is written in Arabic, and there is a great defect in both our Universities, very few spending any of their time to attain to skill either in that or other Eastern Languages... every Ship of yours, at every Voyage shall bring home one Arabic or Persian Manuscript Book.'

During the course of the 17th century the number of Arabic and Persian manuscripts in the Bodleian library at Oxford increased from just a few items to several thousand, with the books and manuscripts gathered by Laud forming the core of this invaluable collection. Moreover, the history of many of these manuscripts shows that they were not collected for the sake of collection, but were actively used in research.

The Bodleian's important collection had a librarian to match. Thomas Hyde, who later became the Laudian Professor of Arabic and who was a master of Arabic and Persian, was appointed to the Bodleian in 1659 and communicated actively with scientists and philosophers at Oxford, Cambridge and the Royal Society.

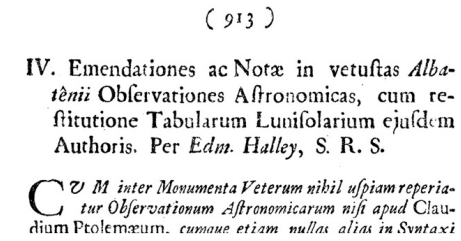
But it was not only silk and manuscripts that were shipped back home through trade routes and diplomatic channels. There were also products like coffee, with its coffee-house culture. Two papers were published in the Philosophical Transactions about the coffee of the Arabs and how the tradition of drinking it in public houses was spreading in England, much to the annoyance of brewers. Coffee houses became an integral part of the intellectual life of the period: many of the Royal Society's earliest Fellows would have held their heated discussions there. New trees and plants also found their way back to England. Three of these trees, imported in 1640, are still alive in and around Oxford.

4. Heavenly problems

Most of the scientists who drew on Arabic and Persian sources were astronomers. Newly developed models of the skies required better observations to support them, and observing something like the Moon over a short period was often not enough: modern observations had to be compared with those made over centuries or even millennia to discover how the trajectory or obliquity of an object evolved in time. Making observations in places such as Alexandria and comparing them with those made there during the ancient Egyptian, Greek and Islamic periods was the only way that 17th-century astronomers could arrive at convincing conclusions to some of the open questions.

To make use of this ancient data, the exact coordinates of the places from which the observations had been made were essential: without these reference points astronomers could make little sense of their observations. Astronomer Edmund Halley (1656–1742) appealed to travellers to make observations that would help calculate such coordinates. In a paper published in the *Philosophical Transactions of the Royal Society* in 1695 he wrote [8]:

'And if any curious Traveller or Merchant residing there, would please to observe, with due care, the Phases of the Moon's Eclipse at Bagdad, Aleppo and Alexandria, thereby to determine their longitude, they could not do the Science of Astronomy a greater service'



(913)

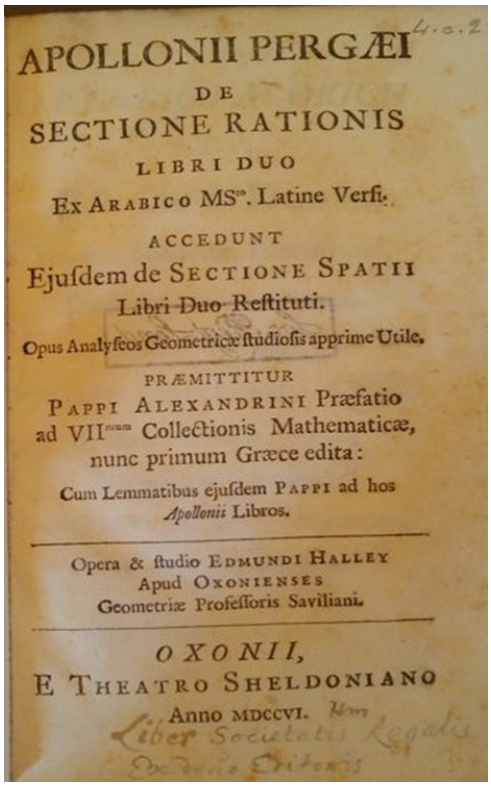
IV. Emendationes ac Notæ in vetuſtas *Albatènii* Obſervationes Aſtronomicas, cum reſtitutione Tabularum Luniſolarium ejuſdem Authoris. Per *Edm. Halley*, S. R. S.

CUM inter Monumenta Veterum nihil uſpiam reperiatur Obſervationum Aſtronomicarum niſi apud Claudium Ptolemæum, cumque etiam nullas alias in Syntaxi

Figure 2: The title of the paper written in Latin by Edmund Halley on the observations of Al-Battani published in the *Philosophical Transactions of the Royal Society* in 1693. *Image courtesy of the library of the Royal Society*.

These comparisons of old and new observations would sometimes pose new questions. The debate on the acceleration of the Moon (the possible increase in the Moon's mean rate of motion relative to the stars) was started by Halley in a paper on the observations of Muslim astronomer Al-Battani (c. 858–929), published in the *Philosophical Transactions of the Royal Society* of 1693 [9] (Figure 2).

Halley particularly valued ancient and medieval observations and excelled at using them. In his paper on Al Battani‘s observations, he notices that they fall half way between his own observations and those of the Greeks (around 800 years each way). He also points out that Al-Battani was the first to dare to criticise Ptolemy [10]. His starting point for the debate on the acceleration of the Moon was an attempt to restore Al-Battani's observations of the eclipses at al-Raqqa [11]. To do this, he needed to correct the two available Latin translations of Al-Battani's work, which he thought were full of errors, and hoped he could lay his hand on a reliable copy:



APOLLONII PERGÆI

DE

SECTIONE RATIONIS

LIBRI DUO

Ex ARABICO MSº. Latine Verſi.

ACCEDUNT

Ejuſdem de SECTIONE SPATII

Libri Duo Reſtituti.

Opus Analyſeos Geometricæ ſtudioſis apprime Utile.

PRÆMITTITUR

PAPPI ALEXANDRINI Præfatio

ad VIImum Collectionis Mathematicæ,

nunc primum Græce edita:

Cum Lemmatibus ejuſdem PAPPI ad hos *Apollonii* Libros.

Opera & ſtudio EDMUNDI HALLEY

Apud OXONIENSES

Geometriæ Profeſſoris Saviliani.

OXONII,

E THEATRO SHELDONIANO

Anno MDCCVI.

Figure 3: Title page of Halley's translation of Apollonius's work from Arabic. *Image courtesy of the library of the Royal Society*.

Halley's wish did not come true. But had he laid his hands on such a manuscript, he would no doubt have translated it himself: when he located the Arabic version of the work of Greek mathematician Apollonius (c. 262 BCE-c. 190 BCE) on conic sections, he took on the pain of learning Arabic at the age of 50, with very limited resources, in order to translate it into Latin (Figure 3).

The debate on the acceleration of the Moon was followed up by other astronomers, including Richard Dunthorne (1711–1775), Roger Long (1680–1770) and Pierre-Simon Laplace (1749–1827). All of them used Al-Battani's observations in addressing this question, which was only settled by John Adams (1819–1892) in 1853 [10].

5. Reaching out

As Europe expanded into the rest of the world, it discovered another two good reasons for paying attention to Arabic sources and the Arabic language.

First, 'the rest of the world' had been well described by those who had expanded into it and travelled through it before the Europeans – the Muslims. The books of Arab geographers like Abu al-Fida (or Abulfeda, 1331–1332) became important: they not only described in detail the geography, natural resources and people of these countries, but also included carefully measured coordinates of cities and places, making such books valuable to astronomers as well as geographers.

Abulfeda's book *A Sketch of the Countries (Taqwim al-Buldan)* was much sought-after in the 17th century. In 1650, the astronomer and orientalist John Greaves (1602–1652) translated parts of it; a more complete attempt was made by French scientist and orientalist Jean de Thévenot (1633–1667). He struggled to finish his translation, as he explained in a letter to the secretary of the Royal Society in 1671:

'I should tell you sir that I found myself engaged in the translation of Abulfeda, which is an undertaking in which the difficulty of the language is the least [impediment]; the scarcity of Oriental historians and geographers up to the present has given me more trouble than anything else.'

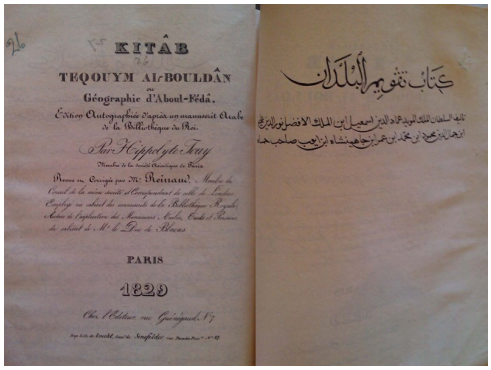

KITÂB
TEQOUYM AL-BOULDÂN
Géographie d'Aboul-Féda,
PARIS
1829

Figure 4: Title page of the Arabic *Taqwim al-Buldan* of Abu al-Fida which was printed in Paris in 1829. *Image courtesy of the library of the Royal Society*.

Abulfeda's book remained important well into the 19th century and was printed in Arabic in 1829 in Paris. See Figure 4 for the front page of this edition, which is in the library of the Royal Society.

The second attraction of Arabic for an expanding Europe was its value for diplomatic and trade relationships over a substantial part of the world. In his inaugural lecture, the orientalist William Bedwell (1561–1632) gives this as a compelling reason for studying Arabic. After demonstrating the wide geographical area in which the language is spoken, he says:

'In almost all these places, the privileges and diplomas of kings and princes, the instruments and contracts of merchants and nobles, finally the familiar letters of all, are expressed and written almost solely in Arabic language.'

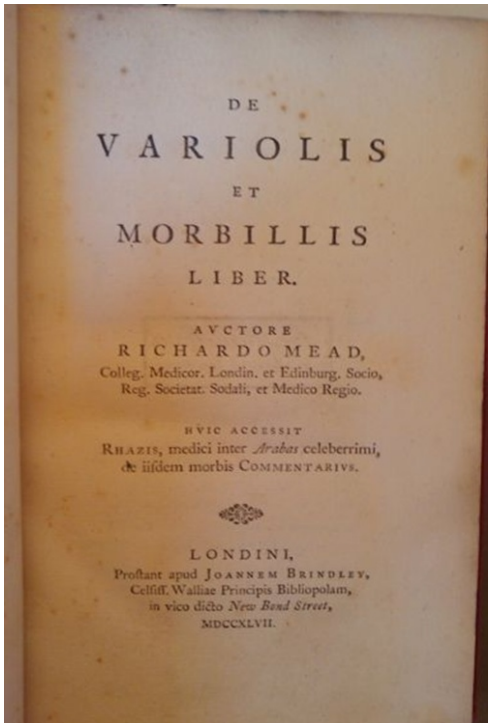

DE
VARIOLIS
ET
MORBILLIS
LIBER.
AVCTORE
RICHARDO MEAD,
Colleg. Medicor. Londin. et Edinburg. Socio,
Reg. Societat. Sodali, et Medico Regio.
HVIC ACCESSIT
RHAZIS, medici inter *Arabas* celeberrimi,
de iisdem morbis COMMENTARIVS.
LONDINI,
Prostant apud JOANNEM BRINDLEY,
Celsiss. Walliae Principis Bibliopolam,
in vico dicto *New Bond Street*,
MDCCXLVII.

Figure 5: Title page of Richard Mead's book in which he incorporated the work of Al-Razi and commented on it. Note Al-Razi's name on the title page. *Image courtesy of the library of the Royal Society*.

6. Search and research

Arabic materials were used for research in several different fields during the 17th century. The mathematician John Wallis (1616–1703) used Arabic quotations in his work and translated a proof of Euclid's fifth postulate by Al-Tusi (1201–1274), which he used in his lectures and later included in his book *Opera Mathematica*. He was assisted by the Arabist Edward Pococke (1604–1691), who showed him two other solutions in Arabic sources.

In medicine, there is the example of Richard Mead (1673–1754) who in his book on smallpox and measles *De variolis et morbillis* (Figure 5) found it necessary to translate the work of Al-Razi (865–925), the first physician to write about these diseases. The translation, by Thomas Hunt (1696–1774), Laudian Professor of Arabic, was included with a commentary by Mead and formed a large part of his book.

Robert Boyle (1627–1691, originator of Boyle's law) was also influenced by the works of Muslim scholars [12]. He was close to several orientalists, such as Pococke and Hyde. Hyde often provided Boyle with information from Arabic and Persian manuscripts, writing in a letter to Boyle that *'if for the future I meet with anything in oriental authors, that may illustrate natural knowledge, I shall be sure to take notice of it.'*Arabic and Persian astronomical tables and star catalogues were also invaluable in research. In 1663, Hevelius wrote to Henry Oldenburg (c. 1619–1677), the secretary of the Royal Society, asking about a copy of the famous star catalogue of Ulugh Beg that he had heard about from John Wallis. Wallis knew of a reliable copy in Oxford, and the Royal Society asked him to acquire a translation. Hyde was the obvious person for Wallis to consult, as he had already begun a translation of the catalogue and was trying to finish it.

Wallis helped Hyde complete the translation, which used and compared three different Persian manuscripts of the Ulugh Beg star catalogue, two of them in the Bodleian library and the third a manuscript in St John's College belonging to William Laud (1573–1645), Chancellor of the University and later Archbishop of Canterbury. Once Hyde had added the 16th-century star catalogue of the Arab astronomer Al-Tizini to his

translation, the finished product (Figure 6) was published in 1665 and a copy sent by the Royal Society to Hevelius without delay.


جداول مواضع ثوابت الكواكب طول عرض
جريافته است الغ بيك بن شاهرخ بن تيمور
SIVE
TABVLÆ
LONG. AC LAT. STELLARUM FIXARUM,
EX OBSERVATIONE
ULUGH BEIGHI,
TAMERLANIS Magni Nepotis, Regionum ultra citràque GIHUN (i. Oxum) Principis potentissimi.
Ex tribus invicèm collatis MSS Persicis jam primùm Luce ac Latio donavit, & Commentariis illustravit, THOMAS HYDE A. M. è Coll. Regin. Oxon.
In Calce Libri accesserunt MOHAMMEDIS TIZINI Tabulæ Declinationum & Rectarum Ascensionum. Additur demum Ejusdem Nominum Stellarum.
OXONII,
Typis Henrici Hall Academiæ Typographi, Sumptibus Authoris. Venales prostant apud Richardum Davis Bibliopolam. CIↃIↃCLXV.
Soc. Reg. Lond.

Figure 6: The title page of Thomas Hyde's publication of the star catalogue of Ulugh Beg and that of Al-Tizini. *Image courtesy of the library of the Royal Society.*

7. Arabick material in the collections of the Royal Society

The evidence of the 17th century interest in Arabic resources manifests itself in several in the libraries and archives of several distinguished academic institutions such as The Bodleian Library in Oxford and the library of the Royal Society. Highlights of the collection of the Royal Society are given here as an example.

Early Fellows of the Royal Society wanted to extend their experimentation and observation beyond their own space and time, even if this meant learning Arabic in order to decipher the flood of Arabic and Persian manuscripts sweeping into seventeenth-century England. Evidence of this interest is demonstrated in many parts of the Society's archive and library. First there are all the books on the shelves marked ‘Arabic Books' which remain not catalogued. In addition to classical Arabic books such as Ibn Sina's Canon of Medicine and al-Idrisi's Geography, it also includes books in Persian, three beautifully illustrated books by the Ottoman scholar Katip Çelebi and even books in Syriac. Another collection of oriental manuscripts have been given to the British Museum, this one consist mainly of books on theology and Arabic language.

Two large collections of Arabic and Persian manuscripts formerly belonging to the Royal Society are now housed at the British Library, including manuscripts on astronomy, mathematics, and medicine as well as grammar, history and literature.

The Society also has a considerable collection of books translated from Arabic, such as Ibn al-Haytham's Book of Optics and the Astronomy of Al Fergani. Some of these, including the star catalogue of Ulugh Beg, were translated by Fellows of the Royal Society or at the request of the Society. Several of these works have hand written annotations in their margins.

Many references to oriental learning and oriental tongues appear in the correspondence of the Royal Society, with the names of scholars like Abu Al Fida of Hama (or Abulfeda) (1273-1131) or places like

Aleppo appearing frequently. There is also evidence of interest in contemporary knowledge: letters were sent to the Levant and North Africa with long lists of enquiries such as ‘what kind of learning they now excel in' and ‘the way used for redeeming their ores into metals.'

There is further evidence in *The Philosophical Transactions of the Royal Society.* Papers were published about a wide spectrum of subjects, such as the observations of classical Muslim astronomers, the medical use of herbs in Aleppo, the method of inoculation against smallpox in Aleppo, and even the manner of hatching eggs in ovens in Cairo! Fellows who lived or travelled in the Levant also wrote books, including the splendid Natural History of Aleppo by Alexander Russell and the first detailed drawing of the eternal city of Palmyra.

Nearly forty Fellows from the seventeenth and eighteenth centuries were involved in this ‘Arabick interest' in one way or another. Five were professors of Arabic, including Edmund Castell, who devoted his life to compiling an elaborate dictionary of oriental tongues and who ordered his memorial stone to be engraved in Arabic, creating what is now England's oldest Arabic inscription.

During the same period the Royal Society elected three Arab Fellows, one of whom, Cassem Aga, made a valuable contribution to smallpox immunisation. Some Fellows such as John Wallis and Richard Mead used actual Arabic quotations in their work.

8. Arabick acknowledgment

The value of Islamic science to early modern science was not simply as material for the history of science. As demonstrated above, most of the interest was initially in the actual science and the philosophy behind it. But science constantly moves forward, making what lies behind it ‘history'. Gradually, collections like that of the Bodleian became more valuable as resources for the history of science rather than for science itself.

It is remarkable, however, that many scientists of the 17th and 18th centuries were able to use Islamic resources for their scientific content while at the same time demonstrating their understanding of where the contributions of Arab and Muslim scholars fit within the history of science. Roger Long demonstrated this brilliantly in his five-volume book *Astronomy*, published in 1742. In this, he often uses the observation of Muslim astronomers like Al-Farghani and Al-Battani. In the debate about the obliquity of the ecliptics alone, he included 12 Arabic values of the observed obliquity. In the same book, he devotes a chapter to ‘Astronomy of the Arabians, Persians and Tartars'. He begins by stating that:

‘From the year 800, almost to the beginning of the 14th century, Europe was plunged in darkness, and the most profound ignorance; but during this period several able men arose among the Arabians, and chiefly at Bagdad, which is very near the ancient Babylon; and some useful works were preformed by them.'

Long continues to demonstrate a very wide knowledge of the history of Arabic and Islamic science and cites many names such as Al-Tusi and Thabit ibn Qurra (836–901) and demonstrates that his knowledge of that period in history of science stretches also to mathematics:

‘It is undoubtedly, to the Arabians that we are indebted for the present form of trigonometry; for although Ptolemy rendered the theory of Menelaus much more simple, yet he worked by very laborious rules.'

Clearly Long, like many other scientists from that period, such as John Flamsteed (1646–1719, Astronomer Royal) and Christopher Wren (1632–1723, architect of St Paul's cathedral), openly acknowledged the contribution of the Arabs and Muslims to science and philosophy, and demonstrated wide knowledge of this contribution.

Modern astronomers and scientists rarely make such acknowledgements or demonstrate such knowledge. This is more a reflection of the way science has progressed, with scientists becoming increasingly specialised and rarely crossing the boundaries of their disciplines, than deliberate ungratefulness. Unfortunately, scientists like Boyle and Robert Hooke (1635–1703), who were able to ponder science, philosophy, history and religion alike, are scarce among modern scientists.

Abundant evidence for the interest in Arabic and Islamic science during the early modern period can be found in the libraries and archives of many important institutions: the Royal Society, the French Academy of Science, Oxford and Cambridge. The sheer number of Arabic and Persian books in the libraries of such institutions and the number of English and Latin translations of the works of Muslim scholars shows how strong this interest was. More research is needed to fully unveil this little-known episode in the history of science.

9. Notes

[1] See for example George Saliba, *Islamic Science and the Making of the European Renaissance.*Cambridge, Mass.: MIT Press, 2007.

[2] The full name of this institution is ‘‘The Royal Society of London for Improving Natural Knowledge'; it was founded in 1660 and is the oldest continuously existence scientific society on Earth.

[3] Güll Russell (editor), *The 'Arabick' Interest of the Natural Philosophers in Seventeenth-Century England'.*Leiden: Brill, 1994.

[4] Arabist Edmund Castell FRS for example mentioned the use of Arabic for understanding Avicenna's medical work in his inaugural lecture. Matthias Pasor who lectured Arabic in Oxford early in the 17th century campaigned for a chair in Arabic quoting the wide geographical distribution of those who speak it, and its usefulness for theology and sacred literature. The works of the Arabs in medicine, philosophy, physics, mathematics, history, poetry, geography, and astronomy are praised.

[5] A prestigious chair in astronomy at Oxford University that was established by Savile in 1619. The chair still exists and is now occupied by the renowned astronomer Joseph Ivor Silk.

[6] From a letter he sent to Ussher on the 3rd of October 1626.

[7] A problem in spherical optics that comprises drawing lines from two points in the plane of a circle meeting at a point on the circumference and making equal angles with the normal at that point. The problem was only solved in 1997 by Peter Neumann.

[8] *Phil. Trans.* 1695 19:160-175; doi:10.1098/rstl.1695.0023. See online here.

[9] *Phil. Trans.* January 1, 1693 17:913-921; doi:10.1098/rstl.1693.00. See online here.

[10] Raymond Mercier, "English Orientalists and Mathmatical Astronomy", in G. Russell (edit.), *The 'Arabick' Interest of the Natural Philosophers in Seventeenth-Century England*, op. cit., pp. 158-214.

[11] City in northern Syria where Al Battani made most of his observations.

[12] See Charles G.D. Littleton, "The Levant in the Intellectual Life of Robert Boyle', in Alastair Hamilton, Maurits van den Boogert and Bart Westerweel (eds), *The Republic of Letters and the Levant*, Intersections

series (Leiden: Brill, 2005), pp. 152-71.

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